Biostratigraphy and Paleoenvironmental Analyses of Pleistocene NJ Shelf Sediments

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LONG-TERM GOALS

The long-term goal of this project is to understand the patterns and timing of latest Pleistocene sedimentation in the Geoclutter area of the NJ margin. Paleoenvironmental reconstructions of the study area were developed using benthic foraminifera and sediment texture analyses of drill cores obtained in Fall 2002 using the ACHC-800 from the RV Knorr. This award has been extended through May to facilitate sediment texture analyses by graduate (masters) student R. J. Turner and the synthesis of paleoenvironmental analyses by Christensen.

OBJECTIVES

The scientific objectives of this study are to: 1) reconstruct paleoenvironment using a multi-proxy approach; 2) evaluate sediment for provenance and sediment transport history using heavy mineral concentrations, sediment texture and radiochronology; and 3) integrate these data with other geological and geophysical data generated by rest of the scientific party to develop an integrated stratigraphy and history of deposition. This work provides a means of ground-truthing interpretations of geophysical data, and explaining variations in environment as a function of sediment source, age, and mineralogy.

APPROACH

1) *Faunal Analyses and Paleoenvironmental Reconstructions*. Paleoenvironmental reconstructions are based primarily on benthic foraminiferal faunal analyses and include supporting data such as grain frosting, macrofauna, and floral data. Benthic foraminifera have affinities for certain water depths and/or environmental conditions, and so are useful indicators of provenance and transport. The depth associations of benthic foraminifera on the NJ shelf are well documented (e.g., Katz et al., 2003) and provide the species concepts used to identify individuals. Paleobathymetric estimates are based on neritic (0-200 m) subzonations [inner (0-50 m); middle (50- 100 m) and outer (100-200 m)] and transitional (estuarine, beach) and non- marine (fluvial) environments. Foraminifera are also used to identify transported sediments, which often contain a mixture of faunas: the *in situ* assemblage appropriate to the water depth, and a displaced shallower water fauna. Similarly, planktonic foraminifera will provide supplemental data about the prevailing surface water conditions when present in statistically significant numbers. Identification of the source of sediments transported within mud clasts provides important information about depositional processes such hydrodynamic spatial information, essential data for interpretations of the sediment texture, depositional environmenta, and the geophysical data. We had hoped to develop a macrobenthic invertebrate database as well, but there

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are too few individuals to permit this. The presence of ostracods and bivalves are noted. Previously collected grab samples were provided by Goff for foraminiferal (and sediment) analysis by Christensen to determine the modern surface sedimentation patterns in the study area and aid in downcore interpretations.

2) *Sediment Provenance.* We attempt to differentiate sediments derived from the NJ/ PA Appalachian region and subsequently transported by glacio- fluvial mechanisms, from sediments derived from other regions and transported by icebergs. Regionally derived sediments are distinguished from allochthonous sediments (likely with a Maine origin) using heavy mineral separations, textural analyses on the SEM, and dating of hornblende, zircon and rutile.

The mineralogy of reworked surface sediments of the NJ shelf is dissimilar to that of the adjacent coastal plain: abundant hornblende, garnet and magnetite are not evident in Cenozoic coastal plain rocks (Frank and Friedman, 1973). Furthermore, glaciers were proximal to the study area and icebergs likely grounded on the shelf (Duncan and Goff, 2001). The mineralogic study of the core sediments should enable differentiation of, for example, hornblende- and garnet- rich, coarse- grained fluvial sediments, from glacially introduced ice rafted debris (IRD). Identification of IRD (following the methods of Allen and Warnke, 1991) will permit us to identify glacial expansion (necessary for icebergs to reach the shelf). The assessment of the mineralogy is crucial to understanding the patterns of sediment deposition and erosion on the NJ margin. Potential siliciclastic sediment sources include rivers, Cenozoic coastal plain sediments, relict sediments, and IRD. These sources should yield distinct mineralogy and sedimentary texture, as well as associated biological differences. Our results will provide important constraints on current and future acoustic, sedimentary and paleoenvironmental studies in the Geoclutter study area.

3) *Integrated Analyses.* Correlation of the downcore benthic foraminiferal data with the grain size data generated by Alexander enhances interpretations and discriminates between texturally similar environments. A unimodal, coarse grained sediment may be interpreted as fluvial (but would be identified by the absence of benthic foraminifera), or shallow marine (identified by abundant inner continental shelf benthic foraminifera). Similarly, a mud may be estuarine (and contain abundant marsh foraminifera) or outer shelf (and contain outer neritic benthic and abundant planktonic foraminifera). Planktonic foraminifera are anticipated to provide supporting data, e.g., marsh sediments should contain few if any planktonics whereas abundance should increase in deeper water environments. These comparisons are ongoing, and will be finalized when all of the foraminiferal and sedimentological data have been collected.

WORK COMPLETED

1) Knorr 168 Sites 1, 2 and 3 (= ODP Site 1071 Holes H to P) were sampled for foraminifera at each major facies change, and in occasional clay clasts. A total of 113 samples were taken for stratigraphic analyses and dried, weighed, washed in dionized water through a 63 μm sieve, dried at 60°C, and weighed to determine weight percent sand. This work was performed by two undergraduate students (Robert Neurath and Vanessa Donnelly) and a graduate student technician (Jacqueline Shea). A total of 51 and 10 grab samples were picked for planktonic and benthic foraminifera, sorted into species and counted to determine relative abundance. They were also evaluated qualitatively for grain rounding and texture; an additional 32 samples are being investigated currently. Those samples for which post-cruise investigations revealed some disturbed and re-cored intervals were not analyzed (30 samples).

Foraminiferal data are presented as relative abundance (%). Many samples did not achieve a sufficient numbers of individuals (300) for statistically valid quantitative biofacies analysis, however, the species diversity on the inner to middle shelf is lower than in the pelagic realm and so the relative abundance is probably accurate at lower numbers. These foraminiferal assessments are currently coarse. The completion of the additional 32 samples this fall will increase the detail of the analysis and improve our ability to identify fine scale paleoenvironmental changes.

2) A total of 31 samples grab and 6 downcore samples have been sorted for grain size at 1 phi intervals and separated into heavy minerals using heavy liquid (sodium polytungstate). Hornblende crystals from 5 grab samples were analyzed to determine age using K-Ar methods on an Atomic Absorption Spectrometer 3100 in Wampler's laboratory at Georgia Institute of Technology. This work is being performed by Christensen's masters student, R. Jessica Turner, in association with Marion Wampler (K-Ar dating of hornblende; Georgia Institute of Technology) and Eirik Krogstad (ICPMS dating of zironc and rutile; Georgia State University). Work planned for the fall includes heavy mineral separations using a Frantz magnetic barrier separator to determine weight percent of the heavy mineral suite of grab and downcore samples, dating zircon and rutile in ICPMS lab of select grab and downcore samples, additional K-Ar dating of downcore samples, and SEM sediment grain textural analysis of grab samples. The limited downcore analyses will be performed at significant facies changes as indicated by the CHIRP profiles, and identified in section by foraminiferal (Christensen) and sedimentological (Alexander) analyses.

3) Preliminary foraminiferal analyses have been integrated with grain size and radiocarbon data generated by Alexander, and compared with CHIRP profiles to link paleoenvironmental changes with significant features such as the reflector R.

RESULTS

Faunal Analyses and Paleoenvironmental Reconstruction. Site 1 (~129 m w.d.) penetrated the outer shelf wedge and underlying possible channel infill, as suggested by geophysical interpretations. The benthic foraminiferal assemblage in the upper 100 cm (shelf wedge) is dominated by in situ forms, consistent with modern forms, but the interval below (~125 m and below) is dominated by Elphidium spp. Elphidium sp. is found in high abundances in the inner neritic environment. These results indicate depositional conditions in shallower water conditions until ~125 cm, when water depths deepened to conditions similar to the modern, and permitted deposition of the outer shelf wedge and are consistent with Alexander's ^{14}C dates. His dates indicate deposition of the lower unit occurred in MIS3, when sea level was at a highstand but lower than the modern, and the upper "wedge" unit was deposited between the end of MIS3 (~30 Ka) and the start of MIS 1 (~10 Ka).

Site 2 penetrated ~13 m of channel infill. The uppermost samples are dominated by *Cibicides* spp., found in the middle to outer neritic environment today, and is interpreted as *in situ*. With the exception of the upper 20 cm, the benthic foraminiferal assemblage is dominated by *Elphidium* spp. throughout. *Quinqeuloculina* spp., an inner to middle shelf species that can also be found at low abundances in marsh sediments, is present when *Elphidium* spp. are most abundant. The upper 600 cm are interpreted as marsh sediments although absolute numbers often fall below the statistically appropriate 300 in this interval, and the data are inconclusive. This interval is actually nearly barren, which is consistent with the marsh environmen. Modern marsh sediments contain high abundances of foraminifera near the surface but the environment is hostile to carbonate at depth and so preservation downcore in modern marsh cores is extremely spotty. While the pattern of deposition of these specimens is consistent with modern marsh systems, it does not exclude deposition in an inner shelf environment. The presence of the marsh species *Ammmonia beccarii* at 200 cm also indicates restricted waters. The interval from 600 – 1100 cm, when *Elphidium* spp. are present in statistically valid numbers, is interpreted as inner shelf based on that species affinity for shallow water environments today. The interval from 1100 – 1400 cm has low abundance but is interpreted as marsh based on the elevated abundances of *A. beccarii* and the abundant iron staining of the foraminifera, common in restricted environments. Alexander's ^{14}C data indicate the deposition below 1100 cm is associated with MIS 3, and above 1100 cm with late stage MIS 2.

Site 3 drilled through the flanks of a channel system and penetrated the regional reflector R. Below R, the foraminifera indicate the environment of deposition was similar to the modern (middle shelf). The assemblage is dominated by *Elphidium* spp. (330 and 275 cm) and is interpretted as inner shelf; however, the presence of abundant *A. beccarii* from 336 – 225 cm indicates a marsh component, possibly as part of a successive increase in sea level associated with the termination of MIS 2 and onset of MIS 1. The dominance of *Cibicides* spp. (275 to 125 cm) indicates deposition in middle to outer neritic water depths, similar to modern environments. Alexander's ^{14}C dates indicate deposition below R is associated with MIS 3 but there are no useful dates for the overlying interval.

Analyses of foraminifera (quantitative) and sediment (qualitative) from grab samples from the ribbon-dominated environments indicate a bi-modal population. An inner neritic abraded foraminiferal population associated with rounded, frosted, iron stained quartz is interpreted as relict, and middle shelf assemblage associated with fresh clear quartz grains is interpreted as *in situ.* Sand ridge samples are generally foraminifera- poor, with a uni-modal sediment population and abraded foraminifera.

Provenance. Hornblende crystals all yield an age of approximately 900 Ma, consistent with the Grenville orogeny. It is unlikely that the hornblende grains are Ice Rafted Debris (IRD) from another region with an older basement rock (e.g. Maine). However, these data are averages of a number of grains and may obscure variation. Analyses of individual zircon grains will permit greater certainty.

Stratigraphy. Preliminary relationships indicate the sediments below reflector R were deposited in Marine Isotope Stage (MIS) 3, followed by downcutting associated with MIS 2, and infilling associated with the deglaciation and into MIS 1. It is not yet known if downcutting occurred during MIS 2 or in early MIS 1, however, the results are consistent with a recent study indicating regional continental downcutting (Reusser et al., 2004) between 35 and 13- 14 Ka. The final stratigraphy is dependent upon a complete foraminiferal analysis since it is built on ordinal relationships (although bracketed by the ^{14}C dates determined by Alexander). The foraminifera also provide constraints on the ^{14}C dates, since those dates are determined on material that may be transported (shell and wood).

IMPACT/APPLICATIONS

Paleoenvironmental interpretations provide an essential foundation for acoustic energy – seabed interactions studies. These studies require accurate understanding of the sediments being evaluated, particularly in a region with such great variability temporally and spatially. Geophysical methods (CHIRP, backscatter) can only estimate sediment type and depositional environment and do not offer any temporal context. Furthermore, geophysical methods require estimates of essential parameters such as depth and sediment velocity, which can only be determined from ground truth coring.

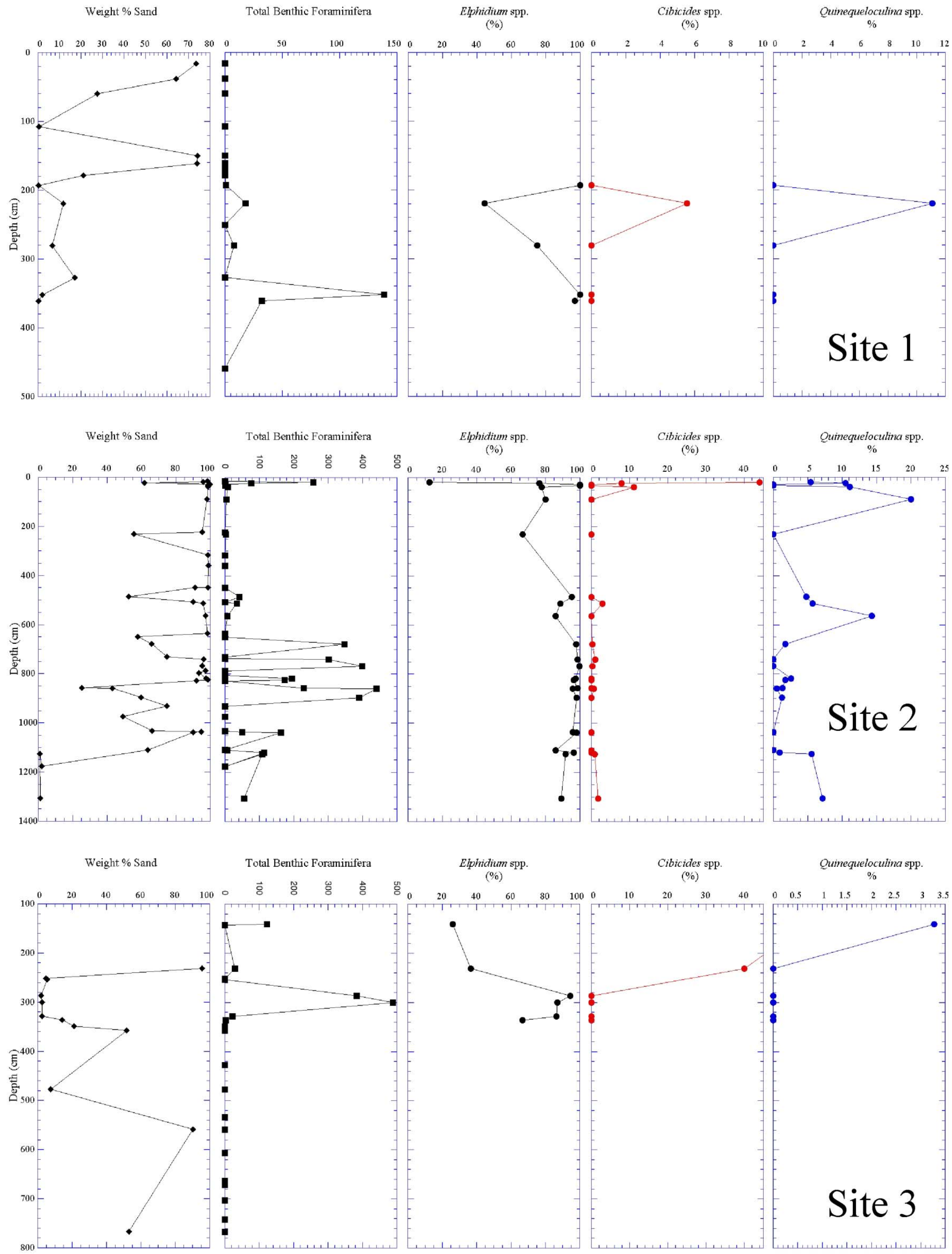

Figure 1. Weight percent sand, total benthic foraminifera, and relative abundances of Elphidium spp., Cibicides spp., and Quinqueloculina spp. Elphidium spp. dominate the inner shelf environment; Quinqueloculina spp. are also associated with this environment. Dominance at the modern middle shelf depths (Site 2 and 3) represents lower sea level or transport. Cibicides spp. are dominant in the middle to outer shelf environments; dominance indicates in situ deposition.

TRANSITIONS

As results are determined, they have been shared with the working group. Goff has incorporated the grab sample data into his recently submitted paper. Alexander and Christensen have discussed the signficance of the preliminary foraminiferal data with respect to his grain size and 14C data, and are preparing a manuscript. Christensen is preparing two manuscripts on the grab sample data and the downcore data.

RELATED PROJECTS

Alexander (SKIO) is developing a paleoenvironmental assessment using grain size parameters, Austin (UTIG), Goff (UTIG), Fulthorpe (UTIG), and UTIG Phd student Nordfjord are providing additional assessments of the regional geophysics using the data from this project. Sommerfield (UDel) is utilizing these data (as well as Alexander's data) to groundtruth his high resolution physical property data, essential for preparation of synthetic seismograms, which in turn permit better interpretation of the high resolution CHIRP data and regional patterns by the UTIG group.

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